Accurate Geminid velocities with CHIPOlAtA

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For several years, the high-resolution photographic camera CHIPOlAtA has been used to acquire precise orbits for Geminid and Perseid meteor shower members. In this paper I analyze the first set of data obtained during the Geminids 2014.

1 Introduction

CHIPOlAtA (Bettonvil, 2014, 2015) is a photographic camera system that is equipped with a precise and fast chopping shutter, enabling precise measurement of the velocity of a meteor. This is the most critical parameter in the determination of its orbit, hence accurate measurement is crucial.

The camera comprises a Liquid Crystal (LC) optical chopper (Bettonvil, 2010), which periodically switches between dark and transparent state up to several hundred cycles/sec[1], much faster than traditional meteor photography, and comparable with the – somewhat slower (100Hz), but more sensitive – CABERNET system as operated in the French Pyrenees area by IMCCE (Vaubaillon, 2014).

High resolution orbit determination is valuable as it permits detection of fine structures in meteoroid streams and provides accurate input for meteoroid stream modelling.

This paper focuses on the reduction of obtained data, in particular the Geminids 2014. In the next Section first a brief description of the instrument setup is given.

2 Instrument description

CHIPOlAtA consists of two Canon 550D 18Mpxl DSLR cameras mounted on the same tripod and aligned such that one long FoV is obtained. With a relatively long focal length of 50mm a field of 18x50 deg^2 is formed, which is always aligned such that the long axis points to the radiant. Each camera has a built-in LC shutter, which are operated synchronously. All data is stored in jpeg format. The sensitivity is set to ISO 6400, exposure time 14s.

CHIPOlAtA is always operated in double station mode, the second station being a wider field, lower resolution system, mostly video, depending on the location of the observations. The two stations together enable trajectory and orbit calculation.

Technical details on the instrumental setup is given in (Bettonvil, 2014, 2015).

3 Data

So far, 4 observing campaigns have been carried out, covering the Perseids and Geminids in 2014 and 2015. Geminids are always observed with chopper frequencies of 200Hz, Perseids -due to their higher velocity- with 300Hz. Preliminary results have already been reported earlier (Bettonvil, 2014, 2015). *Table 1* gives an overview of the collected data. So far ~66 meteors have been captured, of which ~75% were double station.

In this paper I will focus on the data of the Geminids 2014. This campaign was carried out in The Netherlands, as weather in other parts of Europe was too unstable to justify a trip elsewhere. Fortunately, the conditions in The Netherlands turned out to be rather good. Klaas Jobse (Oostkapelle), with his CAMS Benelux cameras, served as the second station (Roggemans et al., 2016).

4 Analysis

Depending on the brightness, trail lengths vary between ~40 and over 200 breaks, and can extend over 2500 pixels long. Bright meteors have easily measurable breaks; the weakest tend to fade out in the background noise. This noise varies from image to image and cannot be subtracted by taking dark fields.

For the analysis presented here, we focus on the three brightest captures, having (visual) brightness's of resp. +1, 0 and –2:

- December 14, 2014, 00^{h}54^{m}55^s UT, magnitude +1
- December 13, 2014, 23^{h}40^{m}26^s UT, magnitude 0
- December 14, 2014, 00^{h}22^{m}44^s UT, magnitude -2

[1] http://www.lc-tec.com/optical-shutter (LC-Tec, 2015)

Table 1 – Overview of all collected data so far during Perseid and Geminid observing campaigns in 2014 and 2015. Shown are location, optics, chopper frequencies, resolution, total number of trails captured, and double station captures. The results of CABERNET (Geminids 2015) are not known yet, and as such the number of double station captures is pending.

Shower	Location	Lens	Cycl/s	Resolution	2nd cam	# trails	# double station
Perseids 2014	Bosnia	50/F2.8	50–200 Hz	21"	none	5	none
Geminids 2014	Netherlands	2x50/F2.8	200 Hz	21"+17"	video	17	13
Perseids 2015	Croatia	2x50/F2.8	200–300 Hz	17"+17"	12M + video	13	10
Geminids 2015	France	2x50/F2.8	200 Hz	17"+17"	CABERNET*	31	?

(*) See Vaubaillon (2014).

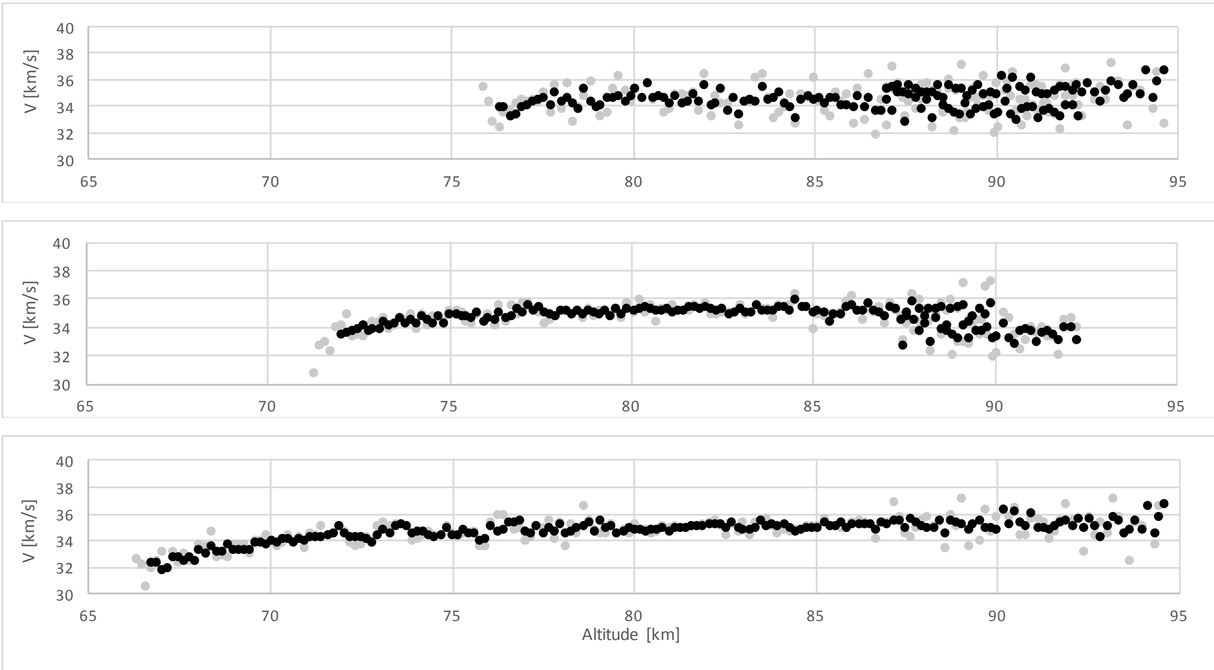

Figure 1 – Velocity profiles for all analyzed Geminids. Top: Geminid +1; Center: Geminid 0, Bottom: Geminid –2. Vertical and horizontal scale for all plots is the same. Grey dots represent a 3pt running average, black dots a 6pt running average.

The data reduction largely follows the method described in (Bettonvil, 2015). Astrometry is done with SAO Image DS9[2], and both the positions of reference stars and meteor breaks measured with the help of the centroid function, which works reasonable well as both stars and meteor breaks are quasi-circular dots. The reproducibility of an individual measurement is typically in the range of 0.2 – 0.5 pxl, which depends largely on the brightness: bright dots are less affected by the background noise.

Plate reduction is carried out with own software[3] and, due to the lack of distortion, is straightforward. Astrometric solutions are typically precise to a couple of arc seconds.

Following the astrometry, the atmospheric trajectory is calculated, again with own software, and based on the method of intersection of planes. The line of intersection represents the meteor trajectory and finally all meteor break measurements are projected on to this line. As a result, the length of the individual breaks in kilometers and also the velocity in km/sec become known.

5 Discussion

Figure 1 illustrates the measured velocity of the three analyzed Geminids. We will now look more closely at this velocity.

First of all, we can conclude that the weakest part of the trail (always the initial part) does indeed give a larger spread in velocities than the brighter parts. In addition, the +1 Geminid trail shows more variation than the brighter 0 and –2 Geminids.

The bright central parts of the 0 and –2 Geminids show stable and constant velocity.

All three meteors, but most strikingly the brightest Geminids, show a deceleration. The brighter Geminids tend, as expected, to reach lower altitudes.

From the distribution of the velocities we are able to say more about the accuracy obtained, which is illustrated in *Table 2*. The average velocity is computed from all data

[2] http://ds9.si.edu/site/Home.html
[3] Meteor35 – Software package for reduction of meteor orbits, including astrometry, atmospheric trajectory calculation and orbital elements, developed by the KNVWS Meteor Section.

in the first half of the trail (and thus the part with the evident deceleration is left out). In first order it is assumed that the velocity of this first part represents V_∞. Over the entire first part the standard deviation amounts from 0.3 to 0.6 km/s per measured dot, or 1–2% of the computed velocity, which amounts to ~0.1–0.2 pxl uncertainty per measured dot. If we assume a constant velocity, the average velocity can be determined with an accuracy better than 0.01 km/s in all cases.

Table 2 – Average apparent velocity and obtained accuracies for the three Geminids.

	+1	0	-2
Average V [km/s]	34.01	35.18	35.05
STDV [km/s]	0.63	0.32	0.41
Error avg [km/s]	0.008	0.005	0.004
Accuracy [km/s]	–	0.05	0.08

The question that then pop ups is if we are allowed to assume that the velocity in the first part is indeed constant? For this reason, the velocity in the brightest central part of the two brightest parts is analyzed a bit more closely: these parts have been split in two and for each of them the average velocity has been computed. The conclusion is clear: in both of these cases the velocity in the first part is higher than for the second half, with a difference of respectively 0.05 and 0.08 km/s for the two brightest Geminids. This allowed us to conclude that deceleration is already present in the brightest part.

6 Conclusions

The above results indicate that rather than averaging the first half of the trail to obtain an estimate for V_∞, a fit based on a deceleration model (e.g. exponential, Gompertz or other) is required. We can conclude that the true V_∞ is therefore slightly higher than the average velocity computed so far until now (with an approx. amount indicated with ‘Accuracy’ in *Table 2*). Exact calculation of V_∞ is to be done and planned for the near future.

7 Future

Until now, Canon 550D DSLRs have been used for CHIPOlAtA. Nowadays much better cameras are available, with both higher sensitivity and lower noise, allowing for a more rapid collection of a large data sample.

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